U.S. ARMY
CORPS OF ENGINEERS
ANNUAL FLOOD DAMAGE REPORT
TO CONGRESS
FOR FISCAL YEAR 1992

INCLUDES
TEN YEARS OF
STATISTICAL DATA
1983-1992

Prepared by the
U.S. Army Corps of Engineers
Engineering Division
in Cooperation with the
National Weather Service
Office of Hydrology

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INTRODUCTION AND AUTHORITY

This report provides information on storm events and associated flood damages and is published annually in response to the House Committee Report 98-217, Energy and Water Development Appropriation Act of 1984. The report includes data on flood damages prevented by projects controlled by the U.S. Army Corps of Engineers (Corps), flood damages suffered and loss of life (as estimated by the National Weather Service). Assessment of damages resulting from other natural (hydrometeorological) disasters are also included. The report represents preliminary estimates available at the end of the fiscal year from a variety of Federal and non-Federal sources. Because of the general nature of the subject and the rapid compilation of the preliminary data estimates, its accuracy and completeness cannot be assured. The information is neither expected to be used for detailed research nor intended to replace subsequent studies. The report data are intended to provide a broad national picture of storm events and the beneficial impact Corps activities and Corps-controlled water projects are having on the Nation.

FLOOD DAMAGES PREVENTED

During Fiscal Year 1992, Corps of Engineers flood control projects and emergency activities prevented an estimated $8.1 billion in flood damages, or 91 percent of the potential flood damage to the Nation. Flood control projects providing protection include dams, levees, channels, pump stations and local protection projects. Emergency activities include technical assistance, materials and construction. The total damages prevented for Fiscal Year 1992 ($8.1 billion) is much less than Fiscal Year 1991 ($17.4 billion) because there were few major floods in the large Mississippi River Basin that is recovering from a drought. Fiscal Year 1986 set the total dollar record for flood damages prevented when $27.3 billion in damages were avoided. For the past 10 fiscal years (1982-1991), flood damages prevented have averaged $13.7 billion annually. Figures 1, 2 and 3 compare Fiscal Year 1992 with previous fiscal years regarding flood damages prevented, flood damages suffered, and the potential flood damages without Federal projects, respectively. The damages prevented in Fiscal Year 1992 (91 percent) compared to the potential flood damages is above normal. When the major storms occur in areas where flood control projects are located, a greater percentage of potential flood damages can be prevented. Many places remain in need of flood protection.

Figures 1, 2 and 3 compare Fiscal Year 1992 with previous fiscal years regarding flood damages

prevented, flood damages suffered, and the potential flood damages without Federal projects, respectively. *All figures and tables appear at the end of this report.*

Table 1 summarizes, by region, the Fiscal Year 1992 flood damages prevented. Table 2(a) summarizes the Fiscal Year 1992 major floods and their effects, while Table 2(b) summarizes other major weather events of the fiscal year, and their effects. *Estimates of damages are not adjusted for inflation.*

Drought gripped much of the West during 1987-1992. While beneficial precipitation in Fiscal Year 1992 eased or erased drought conditions in some locations, other areas were not so fortunate. Two areas in particular, California and the Upper Missouri River Basin, continued to experience serious drought conditions during Fiscal Year 1992 as a result of up to seven consecutive years of below average precipitation. Reservoir storage in both of these areas continued to be very low at the end of Fiscal Year 1992 (September 30, 1992). The subject of drought is further addressed in detail beginning on page 22 of this report.

FLOOD DAMAGES PREVENTED BY CORPS CONTROLLED FLOOD PROJECTS

In Fiscal Year 1992, Corps controlled flood projects prevented an estimated $8.1 billion in flood damages (see Table 3 for a state-by-state distribution). Projects were particularly effective in eight states where flood damages prevented in Fiscal Year 1992 were as much as nine times greater than the 10-year average (Fiscal Years 1982-1991). These states were Alaska, Colorado, Florida, Kansas, Maryland, South Dakota, Texas and Virginia. The last column in Table 3 compares, for each state, the flood damages prevented during Fiscal Year 1992 with the average damages prevented for Fiscal Years 1983-1991. The maps shown in Figure 4 make the same comparison pictorially, for both flood damages prevented (top) and flood damages suffered (bottom).

During Fiscal Year 1992, the three states with the most damages prevented were Texas, Louisiana and California (see Table 3). About 82 percent of all of the flood damages prevented by Corps projects during Fiscal Year 1992 is attributed to these three states. In Texas, serious flooding occurred during the period from December, 1991 into March, 1992 (see pages 8 and 15 for more information on this flood event). Up to 22 inches of rain fell in this three month period. A total of 23 Corps projects reduced the flooding. Five Corps reservoirs set new elevation and storage volume records. Corps levees, pumping stations and reservoir projects protected hundreds of thousands of acres of land from being inundated by floodwaters during this flooding episode. About $5.2 billion in estimated damages were prevented in Texas alone. In Louisiana, although over $1.0 billion in damages were prevented, this amount was still well below the annual average for the state. In southern California, serious flooding occurred in February 1992. Five counties received from 6 to 23 inches of rain within seven days (see pages 4 and 17 for further information on this flood event). Nine Corps controlled projects prevented over $400,000,000 in damages during this flooding episode.

FLOOD DAMAGES PREVENTED BY CORPS SUPPORTED EMERGENCY OPERATIONS

Corps of Engineers emergency activities prevented $2,594,000 in flood damages in Fiscal Year 1992 (see Table 3).

In April 1992, Corps operations prevented $100,000 in damages by providing technical assistance and sandbagging at several downtown businesses and public buildings along McKenzie Creek at Piedmont, Missouri. In June 1992, sandbagging and evacuation of low lying areas in Branson, Missouri saved approximately $200,000 in damages.

During July 1992, a Corps pump was loaned to the city of St. Joseph, Missouri to evacuate flood waters threatening a city sewage treatment plant. Also in Missouri, two pumps were loaned to the Hall Levee District, while sandbags were supplied to the Ray-Lafayette County Levee District along the Crooked River, a tributary of the Missouri River. Sandbags were also supplied to the city of Marysville, Kansas. Flood damages prevented tallied an estimated $300,000. During this same time a sand dredge broke loose from its moorings on the Missouri River near mile 243. The dredge was in danger of striking and damaging river structures and possibly sinking. Therefore, capturing it and tieing it off became an emergency operation which was accomplished by a Corps boat and crew. This action prevented damages estimated at $500,000.

In Texas, the Corps provided technical assistance and sandbags to the City of Cameron to protect an intake structure during heavy spring floods. Estimates of total flood damages prevented amounted to $1,072,000.

In New York, Corps emergency efforts provided technical assistance and emergency operation activities that prevented an estimated $350,000 in damages. A similar situation in the state of Maryland realized $72,000 in flood damages prevented.

STATES WHERE MAJOR FLOOD DAMAGES WERE PREVENTED

Alaska - October 1991

Towards the end of October, 1991 heavy rainfall and flooding hit the Kodiak Island area of Alaska (see page 15). This was a significant flood event by Alaskan standards. Although dollar amounts of damages (both suffered and prevented) compared to other states are relatively small, this represents a large amount for Alaska since the towns and cities in Alaska are generally much smaller than in other states. Since Alaskan towns generally cover less area, have fewer people and contain less property, there is less developed property to be damaged. Corps controlled projects

saved an estimated $10,000,000 in flood damages.

California - February 1992

On February 10, 1992, southern California was hit by a major storm. During a seven day period a wide area within five counties received 6 to 23 inches of rain with lesser amounts in adjacent areas. Peak rainfall amounts measured in the five counties were: 6.2 inches in Kern County, 13 inches in Ventura County, 23 inches in Los Angeles County, 17.6 inches in San Bernardino County and 13.7 inches in Orange County (see further description beginning on page 17). The storm caused widespread damage, and claimed several lives due to flooding and mudslides. Nine Corps flood control projects functioned well. The projects captured part of the extremely heavy runoff, thereby reducing stage levels downstream of the reservoirs. Additionally, flood waters were evacuated faster where Corps channels were in place. Damages prevented are estimated at over $400,000,000.

Colorado - July & August 1992

On July 15, 1992, the eastern Denver metropolitan area experienced very heavy rainfall and major flooding of streets and low lying areas. The worst flooding was in the Aurora area as a result of 1 to 2 inches of rain falling within 2 to 3 hours. Four to six inches of standing water covered Colorado Highway 470 and Interstate 25 (see further description on page 21). Westerly Creek Dam, completed in 1991, operated as a unit for the first time with the Kelly Road Dam and downstream channel improvements. By storing water, these projects reduced flows in Westerly Creek downstream from Lowry Air Force Base (where the dams are located) by approximately 70 percent, preventing an estimated $5,241,200 in flood damages.

On August 24, 1992, another localized flood event hit in and around Denver. Heavy rain of 1.5 to 3 inches occurred along portions of Bear Creek upstream from Bear Creek Dam. The South Platte River ran bankfull through Denver. Bear Creek, Chatfield, and Cherry Creek Dams stored flood water. Although this storage reduced stages on the South Platte River by less than one foot, this amount was enough to keep the South Platte mostly within its banks throughout this highly urbanized area. These three dams prevented an estimated $3,859,900 in flood damages to downstream areas. This represents over 99 percent of the potential damage. Only $8,200 in flood damages were suffered.

Florida - October 1991

A frontal system stalled over central and southern Florida dumping up to 15 inches of rain during the period October 6-8, 1992 (see page 14). Amounts ranged from only 2.5 inches to 15 inches throughout the flat topography of Dade and Broward Counties. The result was localized flooding.

Heavy rains accompanied by strong winds and unusually high astronomical tides exceeded the maximumu capacity of secondary or local drainage systems. The significant astronomical tide raised both high and low tides by about 3.5 feet along most of the east Florida Coast. In Dade and Broward Counties, the high tides blocked the mouths of the rivers and streams. This reduced the amount of time water could drain from the flat land.

Since these high tides were forecast by the National Weather Service several days prior to their occurrence, water control managers released increased amounts of water from coastal structures during the low part of the tide cycle. In addition, all Corps pump stations in Dade and Broward Counties operated at maximum capacity once the heavy rains began. These efforts helped prevent serious flooding from developing and prevented an estimated $4,955,600 in flood damages.

Illinois - April 1992

The Great Chicago Underground Flood

An unusual flood event hit Chicago in April. The flooding was not weather related, but was entirely manmade.

An old system of underground tunnels exists beneath much of downtown Chicago. Built in 1899, the Chicago Freight Tunnels were constructed to distribute freight to downtown businesses. The tunnels, originally about 50 miles long, run under the Chicago River. Currently about 38 tunnel miles remain, though they are no longer used for delivery service.

On April 13, 1992 a contractor to the City of Chicago was driving wooden piling into the floor of the Chicago River to replace old piles. One group of piling was placed south of the original location. Some of these piles ruptured a tunnel wall near the Kinzie Street Bridge. Water from the Chicago River began flowing into the tunnel through an enlarging hole. Within hours the tunnel system had distributed the river water to an area encompassing nearly 18 square blocks beneath downtown Chicago, creating a disastrous subterranean flood. The water flooded dozens of building basements, knocked out electrical and other services, and forced thousands of evacuations, effectively shutting down one of the world's busiest financial districts for several days. The Governor of Illinois declared the City of Chicago a state disaster area as a result of the flooding.

The Corps reduced the water level in the Chicago River, provided three suggestions on how to plug the hole in the tunnel wall, and made its services available to the City of Chicago. The City of Chicago underestimated both the size of the enlarging hole and the means required to stop the flow of water through the hole. About 10 days after the accident, a city contractor, after great difficulty, managed to temporarily plug the hole.

The Corps is credited with quickly setting up a tremendously beneficial coordination network and decision making process among city contractors, architects and engineers, city agencies, building

owners and Federal agencies. Safely removing 770 acre feet of water from the tunnels was a monumental task. The Corps installed automatic water level gages and coordinated the pumps and pumping rates to minimize damage.

The City of Chicago suffered damages estimated in the hundreds of millions of dollars to property and equipment. This estimate *does not include* cleaning costs and monies lost to wages and missed business opportunities.

Kansas & Missouri - July 1992

During July 25-27, 1992, a storm that began over northwest Kansas dropped 2.5 to 3.7 inches of rainfall and moved eastward dropping heavy amounts over northeast Kansas and southwest Missouri. High flows out of Kansas and Missouri caused flooding along the Missouri River at St. Joseph, Kansas City, Waverly, Boonville and Hermann. Corps reservoirs functioned well by reducing stages ranging from five feet at Kansas City to three feet further downstream at Hermann. In Kansas, Tuttle Creek Lake Project precluded an estimated $175,000,000 in flood damages, while Topeka-North and Topeka-Oakland Levees saved an estimated $64,000,000 and $52,000,000 in flood damages, respectively.

Maryland - October 1991 & January 1992

A Corps project known as the Atlantic Coast of Maryland Shoreline Protection Project (also known as the Ocean City Shoreline Protection Project) was completed and dedicated in October 1991. This project protects the coastline from Ocean City Inlet northward along the Maryland Coast to the Delaware state line. It consists of sheetpile bulkheads, sand dunes, and beach raising and widening. Within a month after the completion of this project, a strong storm known as the "Halloween Storm" (see description beginning on page 14) hit much of the Eastern Seaboard, including Ocean City, Maryland and vicinity. On the average, a storm of this magnitude occurs only six times in 100 years. The new Corps project prevented an estimated $32,000,000 in damages, mostly to high-rise hotels and condominiums along the ocean front between 27th-52nd Streets and 68th-88th Streets. Had the project not been in place, damages would have totalled an estimated $47,000,000.

On January 4, 1992, another severe "nor'easter" hit much of the mid-Atlantic region, including Ocean City and vicinity. On the average, a storm of this magnitude occurs only twice in 100 years. The Ocean City Shoreline Protection Project prevented approximately $61,000,000 in damages to ocean front residential and commercial properties. Had the project not been in place, damages would have totalled an estimated $80,000,000.

Puerto Rico - January 1992

On Sunday, January 5, 1992 (Three Kings Eve holiday), a cold front along with an upper level trough produced heavy showers and thunderstorms over most of the island (see description on page 16). The heavy rainfall overwhelmed the catchment areas of creeks and rivers, resulting in severe flash flooding.

Strong thunderstorm activity continued throughout the night and into the early morning hours of Monday, January 6. By sunrise Monday, most of the shower activity was over, but the rivers were very high. By noon that day, most of the river water levels were returning to near normal and the threat of additional flash flooding was over.

A total of 19.6 inches of rain was measured at Cayey during a 24-hour period. This is almost twice (176 percent) the previous record amount of 12.8 inches. Most of the rain 18.4 inches) fell in a six-hour period. Widespread areas measured 10 to 12 inches. This was a rare event for several locations. For example, the flood peak that occurred at Rio Grande de Patilla is expected to have an average return frequency of once per 100 years.

The Portugues and Bucana Project, which channels the Portugues and Bucana Rivers through and around the City of Ponce, significantly reduced the flooding. Although not completed, the Cerrillos Dam functioned as designed, storing flood waters and reducing water flow into the Bucana Channel. Flood damages prevented are estimated to be $4,664,800.

South Dakota - June 1992

On June 13, 1992, heavy rains of 2-10 inches and golf ball sized hail fell in Harding County in northwestern South Dakota (see page 20). Basements were flooded, livestock perished, crops were ruined, and damage was done to roads, bridges, and equipment upstream of Bowman-Haley Dam. Crooked Creek drains this area and flows northeast into the North Fork of the Grand River, just upstream from the dam. The mean daily inflow into Bowman-Haley Reservoir (located in North Dakota just north of the South Dakota state line) was the second highest of record. Flood water storage in the reservoir reduced stages on the North Fork of the Grand River at some locations by approximately eight feet. Flood damages prevented downstream by this operation were $3,636,600.

Five days later, a similar storm hit northeast South Dakota. By June 21, 1992, the Big Sioux River crested more than three feet above flood stage 60 miles upstream of Sioux Falls near Brookings, producing lowland flooding. Four days later the flood reached Sioux Falls, where Corps levees prevented an estimated $46,700 in flood damages.

Texas - December 1991-March 1992

A major flooding episode developed in Texas during the latter half of December 1991 and continued into March 1992 (see page 15). Reservoir storage at 23 lakes controlled by the Corps in the state of Texas provided needed flood control and played a major role in reducing downstream peak flows during the period December 1991 through February 1992. Widespread areas of north, central and south Texas experienced one of their largest volume floods of record. Numerous rainfall and flood records were established for December 1991. Many river gaging stations established historical record stages and five lakes established record pool elevations. As a result of this rainfall and flood event, several of these lakes used their spillways for the first time.

The record rainfall and runoff generated during December 1991 and extending into March 1992 caused widespread flooding and loss of pasture land and personal property. The coordinated efforts of the Corps, the National Weather Service and other Federal, state and local agencies prevented additional damages and loss of life from occurring. Flood control storage significantly reduced peak flows downstream of Corps lakes, protecting homes and saving lives. The careful operations of the Corps lakes in Texas prevented approximately $5.2 billion in flood damages, including $26,000,000 in the Neches River Basin, $122,000,000 in the Brazos River Basin, $63,000,000 in the Colorado River Basin, $26,000,000 in the Guadalupe River Basin, $4.5 billion in the Trinity River Basin and $397,000,000 in the Buffalo Bayou Basin. Even with the benefit of flood control reservoirs, Texas experienced significant flooding that caused damages estimated as high as $1.2 billion. The flood encompassed seven river basins. Some of the highlights are given below.

Neches River Basin
$26,000,000 in Flood Damages Prevented

Sam Rayburn Reservoir, a Corps controlled reservoir near the town of Jasper in extreme eastern Texas, received over 22 inches of rainfall during the period December 1991 through February 1992. Inflow volume amounted to 182 percent of the flood control reservoir's storage capacity. The Corps worked closely with the National Weather Service's River Forecast Center in Dallas-Fort Worth and with other state, county and local officials in controlling the flooding and in warning the public of release rates. The top of the flood control pool was exceeded on March 10 setting a record pool elevation of 175.13 feet (national geodetic vertical datum). This level was just 0.83 feet below the spillway crest. An uncontrolled discharge over the spillway would have resulted in flows which would have damaged homes and other structures downstream. Fortunately, heavy rains did not fall in the Sam Rayburn watershed at that critical time, and a serious crisis was averted. An estimated total of $26,000,000 in flood damages was prevented in the Neches River Basin during this flooding episode.

Trinity River Basin
$4.5 Billion in Flood Damages Prevented

Record rainfall in the Trinity River Basin resulted in flooding from Dallas to the mouth of the river in Trinity Bay. The river and its tributaries flow through heavily populated areas covering two major cities and several mid-sized cities with a total population of 4,200,000 people. The basin's diverse flood protection system includes lakes, levees, channel improvements and local flood protection projects. Although there are eight flood control lakes in the basin, only 33 percent of the drainage area is upstream of a Corps flood control reservoir. Only one Corps reservoir in the Trinity River Basin (Benbrook Lake) experienced flow over the spillway. At the peak of the flood, 73 percent (1.2 million out of 1.7 million acre feet) of the flood control storage was occupied. The December-March inflow volumes to each of the eight lakes exceeded the projects' flood control storage capacity. Although reservoirs provided tremendous benefits, both the heaviest rainfall amounts and the greatest flood damages occurred downstream of the reservoirs. Therefore, reservoir discharges were carefully scheduled to avoid contributing to downstream flooding.

Numerous homes were heavily damaged and large acreage of pasture land flooded. Some non-Corps levees built to protect cattle were breached. Richland Creek levee broke, flooding Interstate 45 between Dallas and Houston. Damage was minimized by the Corps excellent levee and channel improvement system which complemented reservoir storage. The Corps reservoirs are credited with reducing the flood level at Dallas by more than 12 feet, and at Fort Worth by about six feet. The reservoir and levee system prevented flooding in an area estimated at about 4,000 acres near the Stemmons Freeway in Dallas. This area is a highly developed commercial and industrial property. Many large hotels, stores and warehouses were spared major damage. The West Fork of the Trinity River flows near the borders of the cities of Arlington, Grand Prairie and Fort Worth. The reservoir storage and levees kept the river from spreading. Over 1,000 acres of a highly developed area in Fort Worth were spared inundation and damage. A total of $4.5 billion in damages were prevented in the Trinity River Basin.

Brazos River Basin
$122,000,000 in Flood Damages Prevented

Located west of the Trinity River, the Brazos River flows from north-central Texas southeastward to Freeport on the southeast Texas Coast. Nine Corps lakes used 59 percent of their flood control storage, capturing approximately 2.4 MAF of flood water. The nine Corps lakes received in excess of four times the normal rainfall in December and twice the normal in both January and February. This resulted in inflow volumes for the month of December that approached the total flood control capacities of the projects. The combined inflows for January and February also approached the total flood control capacities of the lakes. The Little and Yegua River systems received major inflows, and by the beginning of March five of the six lakes (Belton, Stillhouse Hollow, Granger, Georgetown and Somerville) filled and discharged flow over their respective spillways. Only

Proctor Lake (72 percent of the flood control pool) did not fill. At the peak of the flood, the combined flow over the spillways of the Little River lakes was more than twice the channel capacity at Cameron. The Little River system is complex in that the Cameron area is a restricting point. The Little River above Cameron is controlled to 10,000 cubic feet per second (cfs). The successful operation of the Corps lakes reduced the peak flows at Cameron from 222,000 cfs to 109,000 cfs, and at Richmond from 314,000 cfs to 108,600 cfs. The volume of water that passed major control points on the Brazos River for the *six-month* period from October 1991 through March 1992 exceeded the previous *12-month* record. An estimated $122,000,000 in flood damages were prevented in the Brazos River Basin by Corps controlled lakes.

Colorado River Basin
$63,000,000 in Flood Damages Prevented

The Colorado River and its tributaries, located west of the Brazos River, received high rainfall amounts which resulted in record river stages and flows. Major flooding occurred along the Pedernales and Llano Rivers (Colorado River tributaries) causing Marshall Ford Reservoir near Austin to reach a record pool elevation (710.44 feet, national geodetic vertical datum). Several homes were flooded in and downstream of Austin. Record river stages were recorded at Fredericksburg on the Pedernales and at Bastrop and Wharton on the Colorado River. Lake Travis flood control storage reduced the peak flows at downstream locations. Hords Creek Lake, located about 60 miles south of Abilene, exceeded the top of its flood control pool and spilled over the spillway. An estimated $63,000,000 in flood damages were prevented in the Colorado River Basin.

Guadalupe River Basin
$26,000,000 in Flood Damages Prevented

The Guadalupe River and its tributaries, located west of the Colorado River, received as much as 13.86 inches of rain in December 1991, approximately eight times the normal rainfall. Canyon Lake inflow volume in December 1991 was 91 percent of the project's flood control storage. During January and March 1992, Canyon Lake received another 152 percent. Therefore, every opportunity was taken to release flood waters from Canyon Lake when it would not add to downstream flooding. The volume of water that passed major control points on the Guadalupe River for the *six-month* period October 1991 through March 1992 exceeded the volume for any previous *12-month* period. Due to the severity of the downstream flooding and the impact to farmland in the vicinity of Victoria, the Corps implemented a deviation from its normal operating plan that provided a temporary drop in the river level, allowing farmland to drain between rainfall

events. While this did not alleviate all lowland flooding, it did provide for some intermittent relief. Log jams downstream of Victoria, however, resulted in a temporary damming of the river that caused low cropland flooding. The record rainfall generated a large volume of runoff from the uncontrolled areas below Canyon Dam. This caused major damage to farmland, stream bank erosion, and damage to the San Antonio Bay salt water fishery. A total of $26,000,000 in flood damages were prevented in the Guadalupe River Basin.

Sulphur River Basin

This basin is located in northeast Texas and flows eastward into the Red River. Due to heavy rainfall in this area, Cooper Lake, a new Corps project completed in September 1991, was filled to its minimum conservation pool by the end of December 1991, after only three months of operation. It was expected to take *three years* to fill to this level.

Buffalo Bayou Basin

A concentrated rain and flood event hit the Houston and Harris County area of southeast Texas in March, 1992 (see description of this event on page 18). Corps projects in the Buffalo Bayou Basin, specifically the Addicks and Barker Reservoirs, significantly reduced the disastrous flooding downstream that would have approached the historical 1935 flood that led to the construction of these projects in the mid-1940's. Buffalo Bayou flows would have been four times greater without these two reservoirs. Record reservoir levels occurred. Record river stages were experienced on uncontrolled streams. Corps operation of these two reservoirs prevented an estimated $397,000,000 in flood damages.

Virginia - April 1992

On April 20-21, 1992, heavy rainfall and flooding hit portions of the central Appalachian Mountains, including Virginia and North Carolina (see page 18). Inflow into Corps controlled Philpott Lake on the Smith River in extreme southern Virginia raised the reservoir to its second highest level in 29 years of operation. River stages downstream were reduced due to regulation of Philpott Lake. Smith River stage reductions at Basset, Martinsville and Danville were 12.9, 11.6 and 3.6 feet respectively. Total flood damages prevented by this project are estimated at $116,600,000. Over 99 percent of the damages prevented were in Virginia, but a small amount ($55,000) was also prevented in North Carolina.

FLOOD WARNINGS AND PUBLIC FORECASTS

The mission of the National Weather Service (NWS) is to provide weather, river and flood forecasts and warnings, including public forecasts and advisories for all of the United States, its territories, and adjacent waters and ocean areas for the protection of life and property and the economic welfare of the Nation. To accomplish this mission, the NWS cooperates with the Corps and many other Federal, state, local and private agencies. For example, the Corps provides its rainfall data, reservoir outflow data, river stage data and internal reservoir and river forecasts to the NWS. The NWS in turn uses these and other data to develop river forecasts and warnings, flash flood guidance, and both short-range and extended-range water resources forecasts. The NWS also produces outlooks, watches, warnings and other statements to warn the public of threatening severe weather, such as flash floods, tornadoes, hurricanes, thunderstorms, etc. These services reduce the numbers of lives lost and damages suffered. NWS products directly benefit industries such as shipping, aviation, and agriculture, as well as the public. Many of these services have high benefit-to-cost ratios. The NWS is presently undergoing a considerable modernization effort to further improve the accuracy and effectiveness of its products.

FLOOD DAMAGES SUFFERED

Fiscal Year 1992 was an unusual year with respect to flooding. The year was characterized by a very active, damaging and tragic winter period, an uncommonly inactive springtime, and a considerably active summer. As usual, only a very few states escaped the fiscal year without some flood damage (see Table 4).

The total flood damages suffered across the United States and its territories in Fiscal Year 1992 were estimated at $0.8 billion. (Note: Flood damages and deaths caused by storm surges (for example, from hurricanes) and coastal flooding are not included in this report.) This total is well below last year's (Fiscal Year 1991) estimate of $1.7 billion, and less than the 10-fiscal year (1982-1991) average of $2.2 billion, as shown in Figure 2. *Estimates of damages are not adjusted for inflation.* This year's damage estimate was the sixth consecutive below-average fiscal year damage total, and the lowest estimate since Fiscal Year 1988.

It is interesting to note that, with respect to estimated damages and flood fatalities, the least active and most active months of Fiscal Year 1992 were back to back. November 1991 saw total damages estimated at only $200,000, with no flood related fatalities. Meanwhile, December 1991 saw the highest damage estimate and flood related death toll with more than $169,000,000 and 26, respectively. See Figure 5 for the monthly distribution of Fiscal Year 1992 flood losses.

The most persistent flooding during Fiscal Year 1992 occurred across portions of the Southern and Central Plains. Much of this area observed much above average amounts of rainfall, particularly during the winter of 1991 and spring of 1992. Texas suffered the greatest flood damages of any state during Fiscal Year 1992, with total damages estimated at close to $200,000,000, most of which occurred in the massive flood event of December 1991-January 1992. A review of past reports shows Texas led all states in flood damages suffered in both Fiscal Years 1989 and 1990,

while last year fiscal year (1991) Mississippi had the highest damage estimate. Second highest on the damage estimate list in Fiscal Year 1992 was California, with an estimate of more than $90,000,000, nearly all of which occurred in the very wet month of February 1992. Third place went to Puerto Rico, with an estimate of more than $90,000,000, nearly all of which occurred in the tragic *Three Kings Eve* flood event, Puerto Rico's most celebrated holiday.

Table 4 gives a state-by-state distribution of Fiscal Year 1992 flood losses (see also Figure 4, bottom). Data in Tables 5 and 6, provided by the Federal Emergency Management Agency (FEMA), show the estimated damages from flood insurance claims associated with the National Flood Insurance Program. Tables 5 and 6 are for Fiscal Years 1991 and 1992, respectively. Data in Table 5 are close to final, though some further revision by FEMA is still possible. Data in Table 6 are preliminary and are expected to increase as damage claims filed near the end of the fiscal year are processed. Updated values from FEMA for Fiscal Year 1992 will be published in next year's report.

National flood related fatalities[1] totalled 87 in Fiscal Year 1992, compared to 63 deaths in Fiscal Year 1991 (see Figure 5, Table 2a and Table 4). This compares to the nine-fiscal year average (1983-1991) of 110. Flood related fatalities occurred in 19 of the 50 United States and in Puerto Rico. Puerto Rico reported the most flood related deaths during the fiscal year with 25. Texas observed the second highest flood death toll with 19, while Kentucky was third with eight. Flood related fatalities occurred in every month of Fiscal Year 1992 except November 1991. The highest monthly fatality total of 26 occurred in December 1991, while the lowest monthly death count was in November 1991, when no flood related fatalities occurred. There was one catastrophic flash flood event this fiscal year, when 23 persons died in Puerto Rico during the January 5-6, 1992 flood event which struck there. Detailed descriptions of major flood events during Fiscal Year 1992 follow below. Other sections discuss drought, tornadoes, tropical cyclones, and other major weather events.

MAJOR FLOOD EVENTS

October 1991

Flooding in October caused four fatalities in the United States and its territories, with two in Hawaii and one each in Texas and Puerto Rico. Flood damages across the United States were estimated in excess of $10,000,000. Alaska reported the most damage from flooding during the month, with estimates placed at over $7,000,000.

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[1]Flood-related fatalities are defined (in this report) as those fatalities which are a **direct** result of flooding. **Not** included in this report are **indirect** fatalities, such as vehicle accidents resulting from wet roads, or fatalities due to mudslides, or drownings which occur in non-flood situations. Additionally, fatalities caused by coastal flooding (ocean waves) are also **not** included as flood-related fatalities in this report.

Portions of Florida experienced an extremely wet month in October. As an example, Miami recorded 24.26 inches of rain in October, which is 340 percent of normal. One heavy rainfall episode occurred during the period October 6-10. A frontal system which stalled near extreme southern Florida produced excessive rainfall of 13 or more inches at some locations in Broward and Dade Counties. Localized flooding of roads, vehicles and some homes resulted. The flooding was compounded by high tides which resulted in part from sustained onshore (easterly) winds. These high tidal conditions prevented some rivers from draining as efficiently as normal. Corps efforts during this flooding episode reduced flood damages (see page 5).

During the last few days of October (and into the first couple of days of November), a large, complex and extremely powerful weather system formed over the extreme western Atlantic Ocean. This great "Halloween Storm" affected the entire Eastern Seaboard of the United States, and even further south, down to Puerto Rico. High winds, extraordinary ocean waves and swells, catastrophic beach erosion and major coastal flooding generated by this huge storm were responsible for four deaths (three in New York and one in Puerto Rico) and total damages estimated well into the hundreds of millions of dollars. The most extensive damage was along the coast from New Jersey northward to Massachusetts. The storm received much publicity, in part due to the severe damage it caused at former President Bush's home in Kennebunkport, Maine. The storm's effects continued on into the first couple of days of November. More information concerning this storm system appears later in this report (see sections written on Hurricane Grace and on the "Unnamed" Hurricane, pages 31 and 36, respectively). Corps efforts with respect to the coastal flooding caused by this storm significantly reduced flood damages, particularly in and around Ocean City, Maryland (see page 6).

On October 31 (into November 1), record rainfall hit the Kodiak Island area of Alaska on the last day of the month. The rains resulted in flooding and mudslides which closed roads, damaged houses, and forced the evacuation of at least 150 people. Damage was extensive to roads and utility lines, and the city of Kodiak was declared a disaster area by the governor of Alaska. Corps controlled projects reduced flood damages during this flood (see page 3).

November 1991

November was the quietest month of Fiscal Year 1992 with respect to flooding. Floods caused no deaths, and flood damages were estimated at only $200,000 nationally. Texas reported the most flood damage during the month, estimated at approximately $176,000.

The strong "Halloween Storm" (page 14) mentioned above continued into the first day or two of this month. However, most of the impact of this storm was felt in October.

December 1991

December floods killed 26 people and produced damage estimates of $168,000,000, making December the deadliest and most destructive month of Fiscal Year 1992. Texas recorded 14 flood related fatalities, Hawaii four, Kentucky three, Tennessee and West Virginia two, and Alabama one. Texas once again led the damage list in December, with an estimate in excess of $137,000,000[2].

This month saw the largest and most damaging flood of Fiscal Year 1992 develop. Quite possibly the most voluminous flood in the recorded history of the State of Texas evolved during the latter half of December 1991 and continued into March 1992. Virtually the entire eastern half of the state experienced significant flooding, though four major river basins were hardest hit: (1) the Trinity, (2) the Brazos, (3) the Colorado and (4) the Guadalupe. Dozens of locations along these and numerous other rivers and streams observed record stages or flows, while at least five major reservoirs also set new elevation and/or storage records. The flooding claimed at least 14 lives and caused damages estimated in excess of $137,000,000 (see Footnote 2).

Following wet months during August-October, and a relatively dry November, eastern Texas entered December with above average streamflow and soil moisture conditions. The first half of December brought a continuation of moderate-to-heavy rainfall. Then, during the period December 18-23, excessive rainfall occurred over a huge area of Texas. During this time period, nearly one-half of the state received four or more inches of rain. A rough calculation made to derive the volume of rain which fell during this six-day period indicates that nearly 53 MAF of water fell from the sky, which is comparable to the entire reservoir storage system of the State of California. As an example of the wet weather, Dallas-Fort Worth recorded 8.75 inches of rain in December, more than five times the normal. It was the wettest December on record at Dallas-Fort Worth, which contributed to making 1991 the wettest year on record there (since 1898). A total of 53.54 inches of rain fell in 1991, while the average is only 29.46 inches. Numerous other locations in addition to Dallas-Fort Worth reported similar record rainfall statistics.

The incredible volume of rainfall immediately began to run off of the already saturated grounds, creating widespread flash flooding. Eventually, with nowhere for the water to go, widespread flooding of large rivers and lakes occurred. The river flooding generally peaked during the last week of December and first week of January, but flooding across eastern Texas continued even into March.

When the waters finally receded, the impact became more clear. At least 64 counties qualified for Federal disaster assistance. Major economic losses occurred in the agricultural industry as hundreds of thousands of acres of farmland were inundated by flood waters. Considerable damage was also done to roads, bridges, utilities, businesses and residences[3]. Corps controlled projects and

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[2]Damage estimates for the flooding in Texas have ranged as high as $800,000,000. The estimate used in this report is the best estimate available at the time of this publication, and is based on **documentable** damages from a variety of Federal, state and local sources. Damages associated with this (or any large) flood event are extremely difficult to assess, since the flooding was spread out over a long time frame (from mid-December 1991 into March 1992). Additionally, this flood event actually consists of dozens of smaller flood events, including considerable flash flooding over a very large area. These factors make it very difficult to estimate a single, total-dollar flood damage amount for a flood event of this magnitude.

[3]A comprehensive report on the hydrometeorological aspects of this flood event is currently being prepared by the National Oceanic and

activities significantly reduced flood damages in Texas during this flood, with estimates of savings reaching into the billions of dollars (see page 8).

January 1992

Flood-related fatalities totalled 23 in January, all of them occurring in Puerto Rico. Nearly $88,000,000 in damages were estimated to have occurred during the month. Nearly all of the damages also occurred in Puerto Rico.

The deadliest single flood event of Fiscal Year 1992 occurred January 5-6, 1992 across much of the Commonwealth of Puerto Rico (a United States Territory). A nearly stationary cold front and other meteorological factors combined to produce torrential rainfall over much of the mountainous island, excluding the northwest portion. Many locations reported rainfall amounts of 8-12 inches, while some locations observed as much as 20 inches. The intense rainfall resulted in catastrophic flash flooding as well as some river flooding. The flooding killed 23 people and caused an estimated $88,000,000 in damages. Most of the damage was to bridges and roads, though numerous communities were also hit hard by the flooding. The flooding tragically occurred on Puerto Rico's most celebrated holiday, *Three Kings Eve*. Most of the deaths involved people in motor vehicles, as many people were travelling because of the holiday[4]. Corps controlled projects prevented significant damages during this flood event (page 7).

A compact but very intense storm affected the mid-Atlantic Coast from North Carolina northward up to New York January 3-5, 1992. This storm was much smaller than the huge "Halloween Storm" that affected much of the same area in October 1991 (page 14). In spite of the storm's small size, it caused damages estimated at close to $100,000,000 due mainly to beach erosion and coastal flooding. Some wind damage was also reported, as winds gusted to as high as 89 mph along the Virginia Coast. The center of the storm moved into the Delmarva Peninsula and weakened considerably, thereby sparing New England from any significant impact. No fatalities were reported, though at least 10 wild ponies and 20 deer were killed by the storm on Virginia's Assateague Island. This storm, like the Halloween Storm, dealt a major blow to the Ocean City, Maryland area, for the second time in just a little over two months. Once again, the Corps Ocean City Shoreline Protection Project saved millions of dollars in flood damages (see page 7).

February 1992

Atmospheric Administration (NOAA). This report is expected to be available late in Fiscal Year 1993, and can be obtained by writing to: National Weather Service, NOAA, 1325 East-West Highway, Silver Spring, Maryland, 20910. Attention: Hydrometeorological Information Center - W/OH12x1.

[4]A comprehensive report on the hydrometeorological aspects of this flood event was prepared by the National Oceanic and Atmospheric Administration (NOAA) and can be obtained by writing to: National Weather Service, NOAA, 1325 East-West Highway, Silver Spring, Maryland, 20910. Attention: Hydrometeorological Information Center - W/OH12x1.

Three flood related fatalities occurred in February, including two in California and one in Arizona. United States flood damages were estimated at close to $97,000,000. The highest state estimate this month came out of California, with more than $91,000,000.

A series of storms hit California during the period February 5-16, 1992. The storms produced a variety of weather, including very heavy rainfall and flooding across southern California. Rainfall amounts exceeded 20 inches at some southern California locations during this time period. Two counties in particular, Los Angeles and Ventura Counties, were hit hard by the rainfall and subsequent flooding. In Los Angeles County, the Sepulveda Dam Basin near Van Nuys received much publicity during the peak of the flooding, as the water behind the dam rose as much as 12 feet in just two hours. Dozens of people became stranded and had to be rescued in the vicinity of the dam. The flooding across southern California claimed two lives and caused damages estimated at close to $91,000,000. The series of storms also caused other problems which included mudslides, lightning, heavy snow, avalanches and high winds. Numerous other deaths that were **not** flood related resulted from the storms, as did other damages. Numerous Corps flood control projects prevented hundreds of millions of dollars in flood damages during this flooding episode (see page 4).

March 1992

March flooding caused one death across the United States, which occurred in the state of Texas. Flooding caused damages estimated at more than $59,000,000 nationally. Texas also had the highest monthly damage total, estimated at more than $50,000,000.

On March 4, 1992, rainfall amounts of as much as 10 inches fell in as little as six hours over a 20 mile wide band across Houston and Harris County in Texas. The torrential rainfall produced severe flooding of bayous and streets, which inundated thousands of homes and automobiles and effectively halted all activity across much of Harris County. Thousands of motorists were stranded by the flood waters, as some sections of freeways were described as "flowing rivers." The flooding was described as the worst in Houston in at least 10 years, while some local officials indicated that the flooding was of such magnitude to be expected, on average, once in a 50-year period. The flooding claimed one life and caused an estimated $50,000,000 in damages. Corps controlled reservoirs prevented flood damages estimated well into the hundreds of millions of dollars during this flood event (see page 11).

A strong storm system moved through central New England March 11-12, 1992. Hardest hit was Vermont, where the storm produced considerable rain which combined with snowmelt runoff to produce considerable ice jam flooding. Ice jams in the Winooski River in Montpelier, Vermont caused the worst flooding there since 1927. Damages in Montpelier were estimated in excess of $4,000,000. Damages statewide in Vermont approached an estimated $5,000,000.

April 1992

Flood related fatalities numbered five during April. Two deaths occurred in North Carolina, while Virginia, Oklahoma and Puerto Rico each reported one death. Across the Nation, April floods caused damages estimated at only $9,000,000. This was the second lowest (next to November 1991) monthly total of Fiscal Year 1992, which is unusual in the sense that April is typically one of the highest flood damage producing months of the fiscal year. North Carolina reported the highest damage estimate for the month at over $4,000,000.

A slow moving cold front triggered locally heavy rainfall, flash flooding, and some river flooding over and along the central Appalachian Mountains April 20-21, 1992. The rain and flooding extended from western North Carolina northward through western Virginia, eastern West Virginia, western and central Maryland, and into south-central Pennsylvania. The heaviest rains occurred over the western Virginia highlands, where some locations received as much as 14 inches. The flooding claimed two lives in North Carolina, and one in Virginia. Damages were estimated to be in the low millions of dollars in both North Carolina and Virginia. The flooding was the worst since 1985 across portions of Virginia. Corps controlled projects in southern Virginia prevented flood damages estimated in excess of $100,000,000 in both Virginia and North Carolina (see page 12).

An unusual manmade flood struck underneath the City of Chicago, Illinois in April. Details on this subterranean disaster are found on page 5.

May 1992

May flooding caused three people to perish and more than $39,000,000 in damages. All three deaths occurred in Texas. New Mexico incurred the most damage this month, estimated at more than $32,000,000. May, like April, continued to be unusually inactive with respect to flooding.

As much as 14 inches of rain fell near Hobbs, New Mexico May 22-25, 1992. The heavy rains resulted in severe flash flooding across much of Lea County in extreme southeastern New Mexico. Damages were estimated at close to $32,000,000.

Significant rainfall resulted in considerable flash flooding at isolated locations across much of the state of Texas during May, especially around mid month. The flash flooding claimed the lives of three people and caused combined damages estimated in the low millions of dollars.

June 1992

Five lives were lost as a result of June floods, while flood damages were estimated in excess of

$100,000,000. Two deaths occurred in Florida, while one death occurred in each of the states of Oklahoma, Louisiana and Connecticut. Flood damages for the month were the highest in Florida, where estimates were in excess of $40,000,000. Following a relatively inactive spring, June brought a noticeable increase in the frequency of flash floods across the Nation, as evidenced by the significant increase in damages.

Widespread heavy rainfall fell across much of the East June 4-6, 1992, ahead of and along a slow moving warm front progressing northward up through the mid-Atlantic region and Northeast. The rainfall was locally excessive, with some locations receiving as much as eight inches of rain. Widespread small stream and urban flooding resulted, along with some minor to moderate flooding along some of the smaller rivers. Even the larger rivers showed some significant rises. The most damaging flooding occurred in Connecticut, where as many as 1,000 homes were affected, and evacuations numbered more than 100 people. The flooding in Connecticut resulted in one fatality and damages were estimated at over $10,000,000.

Slow moving thunderstorms dumped heavy rainfall across much of central Kentucky on June 18, 1992. Widespread flash flooding resulted, along with some moderate flooding along the Rolling Fork River. No fatalities were reported, but evacuations of some homes and businesses were required. Damages were estimated in excess of $25,000,000.

Also in mid-June, locally excessive rains hit numerous locations across the Southern and Central Plains. Northeastern South Dakota was especially hard hit, when as much as 20 inches of rain fell in a few days, causing extensive flash flooding and significant river flooding throughout portions of the Big Sioux River basin. Corps projects in both North and South Dakota prevented significant flood damages during June (see page 7).

Still in June, a tropical disturbance in the Gulf of Mexico helped produce excessive rainfall across central and southern portions of Florida June 24-30, 1992. Rainfall amounts for the week reached as high as 28 inches. The rainfall resulted in major flooding across much of central and southern Florida, but especially across west-central portions of the state. The major to record flooding resulted in two flood related deaths as well as damage estimates placed as high as $40,000,000. In some locations, both the rainfall and flooding was of the magnitude that, on average, it would occur once in a period of 100 years or more.

July 1992

July floods claimed 10 lives[5], while damages across the Nation were estimated to be in the vicinity of $59,000,000. Kentucky reported four flood related fatalities, while Ohio and Missouri each reported two, and Kansas and West Virginia each reported one. Ohio had the highest damage estimate for the month at $17,000,000.

[5]One death was also reported in Texas in July that was related to high water (but not flooding). As such, this fatality was not included in this report as a flood-related fatality.

July was an exceptionally active month in terms of flooding, especially across central portions of the country, from the Central Plains east-northeastward into the Ohio Valley. States affected by the flooding included portions of Nebraska, Kansas, Iowa, Missouri, Illinois, Kentucky, Indiana, Ohio, West Virginia, Pennsylvania and New York. Ohio in particular bore the brunt of the bad weather, due to a series of storm systems that produced considerable severe weather in addition to extensive flooding. The worst weather was observed in mid-July, when the Governor of Ohio declared a state of

emergency for numerous Ohio counties. The flooding in Ohio claimed two lives and produced damages estimated at more than $17,000,000.

As part of the general poor weather pattern in July across the Ohio Valley, an isolated but tragic flash flood occurred in southeastern Kentucky July 24, 1992. Four family members were killed by a powerful flash flood that moved down a very small stream.

Corps projects reduced flood damages by millions of dollars in the states of Kansas and Missouri during July (see page 6). Additionally, Corps projects were credited with reducing flood damages in and around Denver, Colorado during July, which was hit by significant local flooding around mid-month (see page 4).

August 1992

Nationally, five fatalities resulted from August flooding, while flood damages were estimated to be in excess of $54,000,000. Two deaths occurred in Arizona, while one death occurred in each of the states of Alabama, Indiana and Kentucky. Indiana reported the highest damage estimate for the month with approximately $32,000,000 in losses. August continued the trend first started in June of having more active weather than is typical for a summer month.

The most spectacular weather event of the fiscal year, Hurricane Andrew (see page 32), moved across Florida and then into Louisiana during August. Ironically, this hurricane had a minimal hydrological impact, as it caused very little flooding[6]. The relatively fast forward motion of the storm kept rainfall amounts from being excessive (see page 34).

Instead, the most damaging flood event this month occurred in Indiana. Nearly stationary thunderstorms dumped as much as 13 inches of rain across portions of central and southeast Indiana in only a six-hour period, with lesser amounts across north-central portions of Kentucky, on August 8, 1992. Severe flash flooding hit a multi county area in Indiana, killing one person and causing damages estimated at close to $32,000,000. The flooding also killed one person in Kentucky and caused an estimated $1,000,000 in damages there.

Oklahoma was also hit by isolated flash flooding in August. In particular, flash flooding in Okmulgee County, in and around the town of Henryetta, on August 5, 1992 caused damages estimate near $10,000,000.

Extremely heavy rains and flooding also hit portions of North Carolina around the middle of August. At least one stream observed record flooding as a result of the heavy rainfall, which

[6]This report does not include damage or death totals caused by coastal flooding. Significant coastal flooding (storm surge) did accompany Hurricane Andrew, but the damages resulting from this coastal flooding are included in the overall damages associated with the storm, rather than separated out. Still, most of the damages caused by Hurricane Andrew were caused by winds, not by coastal flooding.

included over 14 inches in seven days at Goldsboro.

September 1992

Flooding across the Nation was directly responsible for two deaths and damages estimated at more than $85,000,000. One death occurred in both Georgia and Missouri. Iowa reported the highest flood damage estimate, with $48,000,000. September 1992, the final month of Fiscal Year 1992, continued to be more active than usual with respect to flooding.

Portions of Iowa and Wisconsin were hit by waves of excessive rainfall and flooding September 14-20, 1992. In Iowa, southwestern and south-central portions of the state were hardest hit, while in Wisconsin, west-central and southwestern areas were hit the hardest. In both states, some locations reported as much as 17-19 inches of rain, most of which fell in less than three days. The rainfall resulted in excessive flash flooding, as well as some serious river flooding. Many small streams as well as some of the larger rivers in both states observed major to record flooding. Miraculously, no fatalities occurred as a result of the flooding, though combined damage totals for both states were estimated at $75,000,000.

Also in September, a severe flash flood hit portions of the Cherokee Indian Reservation in North Carolina. Locally heavy rains associated with a cold front fell across some mountainous locations in western portions of the state on September 10. Witnesses described a wall of water estimated to be as high as 20 feet which moved down a small stream through the reservation. Surprisingly, no deaths occurred as a result of this violent flash flood, though as many as 2,000 people were evacuated. Damages were estimated at close to $5,000,000.

DROUGHT AND THE BENEFITS OF WATER PROJECTS

Drought conditions continued across much of the western third of the United States during Fiscal Year 1992. In particular, California and upper portions of the Missouri River Basin continued to be locked into a six-year old drought at the close of Fiscal Year 1992. Figure 6 shows drought conditions (Palmer Long-term Drought Index) at the beginning and end of Fiscal Year 1992. Water projects owned by the Corps and others made a very positive contribution toward mitigating some devastating effects of drought.

The weather patterns through February 1993 have resulted in much improved conditions across portions of the West. California state officials recently suggested that the drought may be nearing its end after more than six years, owing to the extremely wet period which affected most of California from mid-December, 1992, through mid-January, 1993. Most important has been the much above average snowfall which has accumulated in the Sierra Nevada so far during the winter of 1992-93. The melting of this snowpack this coming spring is expected to go a long way in replenishing the low reservoir storages that existed throughout California at the end of Fiscal Year

1992. Total elimination of the drought in California and other western states will depend on future precipitation for the remainder of the winter months[7]. More detailed descriptions of Fiscal Year 1992 drought conditions, by specific area, follow below.

Pacific Northwest

Most of the Pacific Northwest continued to observe moderate to extreme drought conditions during Fiscal Year 1992 (see Figure 6). *This area is a notable exception to other areas in the West,* in that the wet weather that affected much of the West after the close of Fiscal Year 1992 (September 30, 1992) ***missed*** most of the Pacific Northwest, passing instead to the south. As such, much of this area, particularly interior sections (east of the Cascades), remains plagued by moderate to extreme drought conditions so far in Fiscal Year 1993. Therefore, the outlook for this area for Fiscal Year 1993 suggests continued water supply problems are possible, though above average precipitation for the remainder of this winter could diminish the likelihood of such problems (see Footnote 7).

Missouri River Basin

Portions of the upper Missouri River Basin (Montana, Wyoming, and the Dakotas) are beginning their seventh year of drought. Calendar year runoff for 1987-92 averaged 85, 50, 71, 67, 89 and 66 percent of average. Calendar year 1992 was another dry year. Much of the Missouri River Basin, especially upper portions, received average or below average precipitation, which resulted in a decrease in water stored in reservoirs. At the close of Fiscal Year 1992, the volume of water stored in the reservoir system was 42.7 million acre feet, which is an approximate 5 percent loss over the end of Fiscal Year 1991. This volume represents approximately 74 percent of the pre-drought average.

Conservative water control management of reservoirs continues to provide widespread benefits to the region by serving the multiple purposes of flood control, navigation, power generation, irrigation, fish and wildlife conservation, municipal and industrial water supply, recreation and water quality. The Lower Missouri River continues to be navigable, aided by water releases from six major Corps reservoirs located in Montana and the Dakotas.

The Fiscal Year 1993 forecast for 84 percent of average runoff is based on recent measurements of the water content of the mountain snowpack in the western portions of the Missouri Basin. The below average inflow will require continued reduced water releases to meet all of the Congressionally authorized project purposes. Long-range studies show that it will take at least five

[7]The National Weather Service (NWS) regularly provides members of Congress with late winter and spring outlooks on National flood potential and water supply conditions in a series of publications generally made available each March, titled the ***National Hydrologic Outlook***. Additionally, NWS offices nationwide continuously monitor local hydrometeorological conditions and provide updates on flood potential and water supply conditions as warranted.

successive years of average reservoir inflow to refill the reservoirs to the top of their depleted multipurpose storage zones. Some water supply problems can be anticipated for portions of the upper Missouri River Basin in Fiscal Year 1993 (see Footnote 7).

Ohio River Basin

At the start of Fiscal Year 1992 (October 1, 1991), serious drought conditions remained across much of the Ohio Basin (see Figure 6). Those conditions, which first appeared in late June of 1991, persisted well into June of 1992. Then a very wet pattern developed across most of the Ohio River Basin late in June. By the end of July, almost all of the Ohio River Basin showed remarkable recovery from the severe to extreme drought conditions that had been in place for the past year. Unfortunately, the recovery from the drought came at the expense of some significant flooding, particularly in Ohio during July (see page 20). By the close of Fiscal Year 1992 (September 30, 1992), all remnants of drought in the Ohio River Basin had vanished. The current outlook for Fiscal Year 1993 is for sufficient water supplies (see Footnote 7).

California

At the end of Fiscal Year 1992 (September 30, 1992), most of California continued locked in a serious drought that was entering its seventh year (see Figure 6). It appeared at that time that this drought, already one of the longest and driest droughts of record in the state's history, would probably continue, at least to some degree, well into Fiscal Year 1993. However, as already mentioned above, a very wet weather pattern developed in mid-December of 1992 and persisted into mid-January 1993. Near record snowfall accumulated across much of the Sierra Nevada during this time period. Partially as a result of this much above average snowpack across much of California's higher elevations, state officials suggested in late February that the worst of the long drought may well be over. While reservoir levels at that time were still below normal, it is expected that when the tremendous amount of water now stored in the mountain snowpack is released this spring upon meltdown, most reservoirs will return to more normal levels. Certainly, any further significant precipitation which falls this winter will act to increase the confidence that this particular California drought is in fact over (see Footnote 7).

Colorado River Basin

Drought conditions continued during Fiscal Year 1992 across the upper portion of the Colorado River Basin, while in lower portions of the basin, drought conditions were essentially erased by the end of the fiscal year (September 30, 1992; see Figure 6). States within the upper portion of the basin that were still experiencing moderate to extreme drought conditions at the close of Fiscal Year 1992 included much of Utah, northwestern Colorado and southwestern Wyoming (see Figure 6).

Meanwhile, so far in Fiscal Year 1993 (beginning October 1, 1992), as already discussed above, a very wet weather pattern became established across much of the West. Due to much above normal snowpacks which have accumulated in the upper portions of the Colorado River Basin as a result of this wet weather pattern, drought conditions have been greatly diminished since the end of Fiscal Year 1992. When the spring melt occurs and the water held up in the vast snowpack is released, reservoirs throughout most of the upper portions of the basin are expected to recover to more normal levels. As such, the current outlook for Fiscal Year 1993, assuming average precipitation, is for sufficient water supplies for all of the Colorado River Basin (see Footnote 7).

While the present water supply outlook for the entire Colorado River Basin is much improved over that of one year ago, major Colorado River reservoirs continued to provide tremendous benefits in Fiscal Year 1992, when severe to extreme drought conditions still remained across upper portions of the basin. Water stored from high runoff years prior to the drought was released for use over the course of the last several dry years, including Fiscal Year 1992. Had the reservoirs not been in place, the impact of the drought would have been much more severe across upper portions of the Colorado River Basin.

Great Basin

Moderate to extreme drought conditions continued across most of the Great Basin (Nevada, western Utah, and portions of neighboring states) during Fiscal Year 1992 (see Figure 6). Once again, tremendous improvement has occurred across this area since the close of Fiscal Year 1992 (September 30, 1992), as in surrounding areas, due to the wet weather pattern of this winter. As a result, the current outlook for Fiscal Year 1993, assuming average precipitation for the remainder of this winter, is for considerably improved water supplies across the majority of this region (see Footnote 7).

Mid- & North-Atlantic Region

Much of the mid- and north-Atlantic region of the United States experienced at least moderate drought conditions at the beginning of Fiscal Year 1992 (October 1, 1991; see Figure 6). While conditions diminished somewhat across this area during the winter and spring months of 1992, pockets of moderate to extreme drought conditions still persisted throughout most of the fiscal year. Finally, drought conditions were nearly erased across this area by the end of Fiscal Year 1992, thanks to precipitation which was generally average or above average during the last few weeks of the fiscal year. As of the close of Fiscal Year 1992 (September 30, 1992), only a couple of small pockets of moderate drought conditions remained (see Figure 6). The current outlook for Fiscal

Year 1993, assuming average precipitation, is for sufficient water supplies (see Footnote 7).

Central Plains & Midwest

Drought conditions which had been in place across portions of the Central Plains and Midwest at the beginning of Fiscal Year 1992 (October 1, 1991; see Figure 6) gradually diminished during the winter and spring months of 1992. With adequate precipitation falling over these areas during the remainder of the fiscal year, only a pocket or two of moderate drought conditions remained at the close of Fiscal Year 1992 (September 30, 1992; see Figure 6). Assuming average precipitation, the current outlook for Fiscal Year 1993 is for adequate water supplies across these areas (see Footnote 7).

OTHER MAJOR WEATHER EVENTS

Tornadoes

An estimated 1,148 tornadoes were reported across the 50 United States in Fiscal Year 1992 compared to 1,200 last year (Fiscal Year 1991). This is the second highest total (next to last fiscal year) since this report to Congress was initiated in 1983 and is considerably higher than the nine-fiscal year (1983-91) average of approximately 932. The year was characterized by a relatively inactive spring and a very active summer.

Tornadoes were reported in every state except Hawaii, Maine, New Hampshire, Rhode Island and Vermont. Even Alaska reported a tornado this fiscal year. Texas reported the greatest number of tornadoes again this fiscal year, as it did last fiscal year, with 175. In spite of the near record number of reported tornadoes, tornado related fatalities were well below normal, estimated at only 11 in Fiscal Year 1992, compared to 45 in Fiscal Year 1991. This is much lower than the nine-fiscal year (1983-91) average of 57, and in fact is the lowest tornado death toll in the ten year history of this report. Tornado

deaths occurred in four of the 12 Fiscal Year 1992 months and in six of the 50 states. Mississippi reported the highest fiscal year tornado death toll with three.

Tornadoes during Fiscal Year 1992 caused total damages estimated at $404,000,000, which ties Fiscal Year 1986 for the lowest damage estimate in the last 10 fiscal years. This compares to last fiscal year's estimate of $651,000,000. The average over the last nine fiscal years (1983-91) is around $590,000,000. Minnesota tornadoes generated the highest fiscal year damage estimate of all states with over $69,000,000. See Table 7 for a state-by-state distribution of Fiscal Year 1992 tornadoes and their effects. Monthly summaries of tornadoes and their impacts are described below.

October 1991

Twenty-two tornadoes occurred across the Nation in October, compared to the average (1953-91) of 23. These tornadoes caused no fatalities, compared to the October average (1953-91) of two. Nationally, tornadoes caused an estimated $2,000,000 in damages. Louisiana reported the highest monthly damage estimate with more than $1,000,000 (two tornadoes). Oklahoma reported the most tornadoes for the month with eight.

November 1991

Tornadoes in November numbered 20 and caused two deaths. November averages (1953-91) 26 tornadoes and three deaths. Tornado damages for the month were estimated at $49,000,000. Illinois reported the highest monthly damage estimate of about $30,000,000 (one tornado). Louisiana counted the most tornadoes with six.

December 1991

Three December tornadoes caused no deaths. December saw the fewest tornadoes of all Fiscal Year 1992 months. On the average (1953-91), December produces 18 tornadoes and three deaths. Tornado related damages were estimated at less than $1,000,000 nationally, the lowest estimate of all Fiscal Year 1992 months. Illinois reported the highest damage estimate of only about $250,000 (one tornado). California, Illinois and Mississippi each reported one tornado in December.

January 1992

No deaths resulted from the 15 January tornadoes. January averages (1953-91) 14 tornadoes and three deaths. National tornado damages were estimated near $1,000,000

for the month, with the highest damage estimate coming from Mississippi, with about $400,000 (one tornado). Nebraska reported the highest state tornado total with six.

February 1992

February 1992 saw 31 tornadoes and no tornado deaths. February averages (1953-91) are 21 tornadoes and five deaths. Damages were estimated in excess of $8,000,000. Florida led the damage estimate list, with about $5,000,000. Florida also reported the most tornadoes during the month with 11.

March 1992

March tornadoes numbered 56, and were responsible for five deaths. The March averages (1953-91) are 53 tornadoes and eight deaths. Three deaths occurred in Mississippi, and two occurred in Alabama. March was the deadliest month of all Fiscal Year 1992 months with respect to tornadoes. Damages were estimated in excess of $20,000,000 nationally, with Mississippi reporting the highest monthly estimate of more than $5,000,000 (four tornadoes). The maximum number of tornadoes reported by a state this month was 14, from Texas.

April 1992

April averages (1953-91) 107 tornadoes and 30 deaths (highest average monthly death rate) nationally, whereas April of 1992 saw only 53 tornadoes and, remarkably, no deaths. Damage estimates for the month were only slightly in excess of $2,000,000, much of which occurred in Michigan with an estimate of $1,000,000 (one tornado). Texas again reported the highest number of tornadoes during April with 22.

May 1992

May tornadoes numbered 137 across the United States, shy of the average (1953-91) of 172. No deaths resulted from the tornadoes, compared to the May average (1953-91) of 21. Damages resulting from all of the tornadoes were estimated at about $8,000,000. The highest damage estimate for the month came from Oklahoma at close to $3,000,000 (25 tornadoes). Texas again reported the greatest number of tornadoes with 43.

June 1992

With June came a dramatic increase in severe weather across the Nation. June totals were 401 tornadoes (most tornadoes of all Fiscal Year 1992 months) and one tornado fatality. June averages (1953-91) 156 tornadoes and 13 deaths. This month's only tornado death occurred in Minnesota. The total damage estimate for the month was over $213,000,000, the highest damage estimate of all Fiscal Year 1992 months. Minnesota's damage estimate of $69,000,000 (29 tornadoes) was the highest of all states. The highest count of tornadoes this month came yet again from Texas, with 67.

July 1992

July produced 215 tornadoes and no tornado fatalities. Averages (1953-91) in July are 84 tornadoes and one fatality. This month an estimated $59,000,000 in tornado damages occurred across the country, with Ohio reporting the highest state damage amount of about $23,000,000. Ohio also led all states in the number of reported tornadoes during July, with 44.

August 1992

In August a total of 115 tornadoes (1953-91 average is 56) were observed. Three fatalities were reported (August 1953-91 average is two). Two deaths occurred in Louisiana, and one occurred in Wisconsin. Tornado damages were estimated at close to $31,000,000 nationally, with the greatest state estimate coming from Louisiana (about $14,000,000 from 16 tornadoes). Mississippi reported the most tornadoes during August with 27.

September 1992

The final month of the 1992 fiscal year saw 80 tornadoes touch down (1953-91 average is 38). No deaths resulted from any of these tornadoes (1953-91 average is two). National damage estimates were close to $9,000,000. Kansas tornado damages were highest with close to $4,000,000 (11 tornadoes). Oklahoma observed the most tornadoes with 16.

Atlantic Tropical Cyclones

Fiscal Year 1992 was close to average in terms of tropical cyclone activity. There were a total of eight tropical systems that reached tropical storm strength[8] (or stronger) in the North Atlantic Ocean, Caribbean Sea and Gulf of Mexico. Seven of these systems were "named" tropical

[8]A tropical storm is defined as a tropical cyclone having sustained winds in excess of 35 mph.

cyclones[9]. In addition, there was one "unnamed" hurricane during Fiscal Year 1992 (November, 1991) as well as one "subtropical" (not truly tropical) storm (April, 1992). The unnamed hurricane has been included in this report (see Table 8) since it was a true tropical cyclone, and has been treated as a named tropical cyclone. Meanwhile, the subtropical storm has not been included, since it was not entirely tropical in nature.

Of the eight tropical cyclones (including the unnamed hurricane) in Fiscal Year 1992, three occurred during the 1991 "hurricane season"[10] and five occurred during the 1992 hurricane season. These numbers show that the end of the 1991 hurricane season was about normal, with two named tropical cyclones forming in October, 1991 (1931-86 average is two) and one forming in November (1931-86 average is less than one). Conversely, the 1992 hurricane season got off to a slow start, with the first named tropical cyclone (Andrew) not occurring until mid-August. During the four month period June 1-September 30, 1992 there were five named tropical cyclones. The long-term average (1931-86) for this period is approximately seven. Of the eight Fiscal Year 1992 tropical cyclones, five reached hurricane strength[11]. For comparison, Fiscal Year 1991 had 10 named tropical cyclones[12], six of which reached hurricane strength. Over the past 10 fiscal years (1982-1991), named tropical cyclones have averaged about nine per year, with an average of about five becoming hurricanes each year. Figure 7 shows the number of named Atlantic tropical cyclones and hurricanes over the last 10 fiscal years.

[9]A tropical cyclone receives a name when it reaches tropical storm strength (see also footnote 8).

[10]Hurricane season is defined each year as the six-month period from June 1-November 30.

[11]A hurricane is defined as a tropical cyclone having sustained winds in excess of 74 mph.

[12]Includes one tropical cyclone (Josephine) named during the final week of Fiscal Year 1990 (see the Fiscal Year 1990 Annual Flood Damage Report). Since this storm survived beyond October 1, 1990 (the start of Fiscal Year 1991), it was also included in last year's report (see the Fiscal Year 1991 Annual Flood Damage Report).

Four of this fiscal year's eight tropical cyclones had, to some degree, a direct impact on the United States. Combined, these four cyclones were blamed for 51 fatalities[13] in the United States and total damages estimated at $20-30 billion (Table 8). For comparison, last fiscal year also had four (of 10) named tropical cyclones which had a direct impact on the United States. Together, these four storms caused 27 fatalities and total damages estimated at over $1.6 billion. Individual summaries of all of the Fiscal Year 1992 tropical cyclones follow.

Tropical Cyclones Affecting the United States

Tropical Storm Fabian *(October 15-17, 1991[14])*

Fabian began as a low pressure area in the western Caribbean Sea. Upon investigation by a National Oceanic and Atmospheric Administration (NOAA) plane, the system was named Tropical Storm Fabian southwest of the Isle of Youth, Cuba on October 15. Fabian moved northeastward across western Cuba and over the Straits of Florida, passing about 30 nautical miles southeast of Miami. The storm then continued northeastward, merged with a cold front and became extratropical on October 17 to the northeast of the Bahamas. In its brief, two day existence, Fabian never developed beyond a minimal tropical storm, with highest sustained winds estimated at only 45 mph. Its main impact was abundant rainfall over portions of Cuba. Since the system only grazed southeast Florida and was very weak, the impact on the United States was minimal. There were no reports of casualties or damages in association with Fabian.

Hurricane Grace *(October 25-29, 1991)*

Grace was one player in a complex and meteorologically unusual storm system. Grace first appeared as a non-tropical low pressure area between Bermuda and the Dominican Republic on October 23. Over the next couple of days, the system gradually intensified and attained some tropical characteristics, so that by early on October 26, the system was strong enough to be classified as a subtropical storm. Over the course of the next day or so, gradual transition from subtropical to tropical storm occurred, and the system was finally classified as Tropical Storm Grace late on October 27, roughly 200 nautical miles west-southwest of Bermuda. Rapid

[13]This includes 50 deaths attributed to Hurricane Andrew, 29 of which resulted from the indirect effects of the storm.

[14]The dates which appear in these and subsequent parentheses include the tropical depression stages of the cyclones. A tropical depression is defined as a tropical low pressure area which has a definite circulation, but with sustained winds of less than 35 mph. A tropical depression is one category above a tropical disturbance, but one category below a named tropical storm.

intensification then occurred with the system being upgraded to Hurricane Grace just several hours later. On October 28, Hurricane Grace suddenly turned sharply eastward, prompting hurricane warnings to be posted for Bermuda. However, the hurricane passed about 60 nautical miles south of the island on October 29, with winds of tropical storm strength, but not of hurricane strength (see Footnotes 8 & 11). No reports of significant damage or casualties were received from Bermuda in association with Grace. After passing east of Bermuda, Grace was overtaken by a cold front later on October 29 and subsequently lost its identity. Concerning the United States, the only impact Grace had was to generate large ocean swells of 10-15 feet which affected the southeast coast of the United States, causing some beach erosion but no reported significant damages or casualties.

The remnants of Grace became absorbed into a huge extratropical (not tropical) storm that formed off of the northeast coast of the United States. This storm, widely publicized as the "Halloween Storm," did eventually wreak great havoc along coasts from the Canadian Maritimes all the way down the United States Eastern Seaboard, even to Puerto Rico and the Dominican Republic. It was this storm (but not Grace) that was blamed for extensive damage (hundreds of millions of dollars) and at least four deaths along the United States Eastern Seaboard due to extraordinary sea conditions, high winds, beach erosion and coastal flooding, including severe damage to former President Bush's Kennebunkport, Maine home.

To add even more complexity to this unusual weather system, in the middle of the huge Halloween Storm a rare late season hurricane (the "unnamed" hurricane) developed. While the formation of this hurricane was certainly unusual and quite interesting, it produced little in the way of impact. Specific information regarding this unnamed hurricane appears below, in the section titled "Tropical Cyclones Not Affecting the United States" (page 36).

Hurricane Andrew *(August 16-28, 1992)*

By far the biggest hydrometeorological event of Fiscal Year 1992, and in fact the costliest natural disaster ever to occur in the United States, this historic hurricane was first recognized as a tropical wave which emerged off of the west coast of Africa on August 14. The system moved westward and gradually strengthened into a depression on August 16, and then became Tropical Storm Andrew on August 17 in the central Atlantic. The first tropical storm of the 1992 Hurricane Season then moved northwestward and encountered conditions which nearly caused the storm's dissipation on August 20. However, the weak tropical storm endured those unfavorable conditions, and on August 21 began to intensify while making a turn toward the west, still several hundred miles east of Florida. Rapid intensification continued, and Andrew became a hurricane early on August 22 and was on a due west track, taking aim on the Bahamas and south Florida. By late on August 23, Andrew was near peak intensity with maximum sustained winds of near 155 mph. This was the same Andrew that just a couple of days earlier was nearly stripped of its name due to its weakened state.

Andrew continued westward and passed through the Bahamas late on August 23 into the early

morning hours of August 24. The impact in the Bahamas included at least four fatalities (three as a direct result of Andrew, and one indirectly) and total damages estimated at close to $250 million. Though weakened from the effects of the Bahamas, Andrew rapidly intensified again after leaving those islands. Strengthening continued right up until landfall in Florida, which occurred near Homestead Air Force Base at about 5:05 a.m. EDT on August 24. Estimates of the strength of the hurricane upon landfall near Homestead indicate that Andrew was the third strongest hurricane of this

century to strike the United States mainland, behind only Hurricane Camille in 1969 (Mississippi) and the unnamed Labor Day Storm in 1935 (Florida Keys).

As shown time and time again in media reports, Andrew caused unimaginable damage during its four hour rampage across south Florida. Damage estimates in Florida currently range from $20-30 billion, with most of the damage caused by the exceptional winds. While there were no official observations of sustained surface wind speeds along Andrew's path in Florida, evidence exists which supports an estimate of sustained winds near 145 mph across southeast Florida. The death toll was surprisingly low, considering the unusual intensity of this hurricane. Fifteen people were killed in Florida (all in Dade County) as a direct result of Andrew, while another 29 fatalities were indirectly attributed to Andrew's wrath in Florida. Concerning storm surge[15], Current Island, near the northern end of Eleuthera Island in the Bahamas, recorded an astonishing surge of 23 feet. Along Florida's southeast coast, a surge of 16.9 feet was recorded in Biscayne Bay, which is a record maximum for the southeast Florida peninsula. Interestingly, there were no confirmed reports of tornadoes in the Bahamas or Florida.

But Andrew was not yet finished with the United States. Already, National Weather Service hurricane forecasters at the now severely damaged National Hurricane Center in Coral Gables, Florida were anticipating another United States mainland landfall, and they were targeting the state of Louisiana.

The hurricane emerged off of the southwest coast of Florida later in the morning of August 24, in a slightly weakened state, and headed into the open Gulf of Mexico, still a very dangerous storm. Once back over warm water, Andrew began a brief period of modest intensification while also gradually turning towards the west-northwest. Early on August 25 the system weakened slightly, yet it was still stronger than when it departed Florida. Later on August 25, upon reaching the north-central Gulf of Mexico, the hurricane began to intensify again, while it also turned toward the northwest and slowed its forward speed of motion. With landfall in Louisiana now virtually a certainty, Andrew passed south and west of New Orleans, then slid along the south-central coast of Louisiana. The hurricane finally pressed inland in a sparsely populated area some 20 nautical miles (nm) west-southwest of Morgan City, Louisiana, during the predawn hours of August 26, with maximum sustained winds estimated in excess of 120 mph. After landfall, the system weakened rapidly to tropical storm strength in about 10 hours while making a recurvature to the northeast.

Andrew caused at least six deaths in Louisiana, including two deaths which resulted from a strong tornado that struck the town of Laplace, even before Andrew made landfall. Total damages in Louisiana have been estimated at close to $1 billion. The highest observed storm surge in Louisiana at the time of this publication was near 7 feet.

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[15]Storm surge is a rise in the sea level which accompanies a tropical cyclone. The water is elevated due to the effects of the storm's strong winds "pushing and piling" the water, and low atmospheric pressure near the storm's center, which allows the water to "raise" somewhat since there is less resistance from the air above it. The storm surge is also affected by tidal, coastal and other factors.

The remnants of Andrew continued on a northeast track toward the mid-Atlantic states. There was considerable concern for a time that Andrew would produce devastating flash floods and mudslides as it crossed the Appalachian Mountains, as other decaying tropical systems have in the past (for example, the remnants of Hurricane Agnes in June, 1972). Fortunately, very little inland flooding was reported, as the remnants of Andrew were moving at a fast enough pace to keep rainfall amounts across the Appalachians relatively low. The decaying storm did produce some heavy rainfall totals across portions of Louisiana, Mississippi and Alabama. The town of Hammond, Louisiana reported the highest rainfall total with 11.92 inches. Still, only modest urban and small stream flooding was reported. Likewise, only very limited flooding occurred along just a couple of the larger rivers across the South, with no significant damage and no deaths attributed to this flooding. Reports of severe weather, including several tornadoes, continued to be received along the track of the decaying tropical system, even as far north as Maryland. But for the most part, Andrew's wrath was spent in Florida, and to a much lesser degree in Louisiana. Indeed, while the direct effects of the costliest natural disaster in United States history were over, the memory of Andrew will no doubt persist for generations to come[16].

Relative to Andrew's effects, flood damages prevented by Corps projects are estimated to be $12,590,800. Corps projects preventing damage include the Central and Southern Project South Dade County Canal System (C-101 through C-112) and flood control canals C-1 through C-9 in the Miami area. Levee 31E, although overtopped, limited landward penetration of the storm surge from Biscayne Bay. Coastal structures and canals lowered groundwater levels in the protected areas prior to the storm, expedited water deliveries out of the affected area during and after the storm, and were prepared to provide flood control protection in the event of heavy rainfall.

After the hurricane passed, initially the Corps of Engineers was tasked with the preparation of plastic roofing and debris removal contracts. Later the Corps participated in the acquisition of emergency generators as well as the acquisition and distribution of potable water. The Corps also provided technical assistance along with the Environmental Protection Agency and local officials to repair existing water supply systems. A few weeks after the hurricane, the Hurricane Andrew Recovery Office was established at the Miami International Airport, the Hurricane Andrew Area Office was established in Kendall, and Corps personnel nationwide were made available for emergency work in South Florida. Concurrently, Broward and Dade Counties and the South Florida Water Management District requested rehabilitation assistance for flood control and shore protection works under Public Law 84-89. Additional Federal Emergency Management Agency (FEMA) missions were then undertaken by the Corps in cooperation with other Federal, state and local officials. These missions included identification of disposal sites, debris removal services, rehabilitation of existing street signs, clearing of destroyed mobile home parks, procurement of

[16]A comprehensive report on the hydrometeorological aspects of Hurricane Andrew is currently being prepared by the National Oceanic and Atmospheric Administration (NOAA). This report is expected to be available late in Fiscal Year 1993, and can be obtained by writing to: National Weather Service, NOAA, 1325 East-West Highway, Silver Spring, Maryland, 20910. Attention: Hydrometeorological Information Center - W/OH12x1.

replacement electrical generators, acquisition of portable toilets and showers, acquisition of ice for refrigeration, school building repairs and modular classroom construction, and temporary garbage collection.

Additionally, the Corps was tasked by FEMA to prepare damage survey reports (DSR's). DSR preparation began in mid-September 1992, and as of mid-November, over 1,400 DSR's had been completed by the Corps.

Tropical Storm Danielle ***(September 22-26, 1992)***

This tropical storm originated in an area of weak low pressure that had persisted off of the southeast coast of the United States for several days. Satellite imagery indicated a circulation about 175 nm south-southeast of Cape Hatteras, North Carolina, and upon being investigated by an Air Force Reserve aircraft, the system was upgraded to Tropical Storm Danielle. Danielle made a slow clockwise loop for the first 36 hours after being named, and then began a north-northwest track towards the North Carolina coast. As the storm moved to a position just east of North Carolina's Outer Banks, it turned northward and increased in strength somewhat, but still remained well below hurricane intensity. Danielle then continued northward, making landfall on the Delmarva Peninsula near Wallops Island, Virginia. From there, the weakening system continued up the peninsula into eastern Pennsylvania, where it eventually dissipated.

In terms of impact, Danielle caused some tropical storm force winds along the Eastern Seaboard from North Carolina northward through the Delmarva Peninsula. The highest sustained wind speed along the coast was about 50 mph at Cape Charles, Virginia. Highest wind gusts ranged up to about 65 mph. A storm surge as high as 5.4 feet above normal astronomical tide was reported at Cape Hatteras. Minor coastal flooding and significant beach erosion was reported along the mid-Atlantic coastline, but damage was minor. One death was attributed to the storm when a sailboat sank in the storm east of New Jersey, drowning one person. Rainfall associated with Danielle topped 4 inches at a few locations, but no major flooding problems were reported as a result of the rain.

Tropical Cyclones Not Affecting the United States

"Unnamed" Hurricane ***(November 1-3, 1991)***

Shortly after reaching peak intensity on October 30 as a non-tropical storm, the great "Halloween

Storm" (see page 14) began to weaken and drift southwestward and then southward on October 31. The system drifted over a portion of the Gulf Stream, an ocean current which moves northeastward off of the mid-Atlantic Coast and is characterized by warm sea surface temperatures. These warmer waters helped to develop thunderstorms near the center of the large non-tropical storm system. By November 1, satellite pictures indicated that a small tropical cyclone had formed within the central part of the large non-tropical storm. Later that same day, an eye formed suggesting that the tropical cyclone reached minimal hurricane strength (maximum sustained winds of 74 mph or greater). Indeed, a very small hurricane was confirmed by Air Force plane investigation late on November 1. Though rare, the formation of a hurricane within a non-tropical storm is not unprecedented.

After reaching hurricane strength, the system moved northeastward and made landfall in Nova Scotia, near Halifax, on November 2 as a rapidly weakening tropical storm. The system dissipated north of Nova Scotia some 10 hours after landfall. This tropical cyclone had no impact on the United States. All the damage observed along the Eastern Seaboard has instead been attributed to the effects of the much larger non-tropical storm (the Halloween Storm) which contained the small hurricane. The impact in Nova Scotia was also rather limited since the tropical system was weakened prior to making landfall.

Hurricane Bonnie *(September 17-October 1, 1992)*

Bonnie formed out of a non-tropical weather system to the east-northeast of Bermuda. The system reached hurricane intensity rather quickly as it wandered basically harmlessly in the open waters of the Atlantic Ocean. After spending about five days as an unexceptional hurricane, Bonnie then weakened to tropical storm strength and began to track steadily east-northeastward across the Atlantic towards the Azores Islands. The tropical storm passed through the Azores (only three days after another tropical storm, Charley, also hit those islands - see next page) with apparently no serious consequences, dissipating just to the east of those islands. Bonnie was somewhat unusual in that the system's entire life, from formation through dissipation, was spent at relatively high latitudes (between 33 and 39 degrees north). There were no reports of casualties or damages related to Bonnie.

Hurricane Charley *(September 21-27, 1992)*

Just a few days after the formation of Bonnie, and much further east, another high latitude tropical system formed several hundred miles southwest of the Azores. Charley drifted north while strengthening, taking about two days to reach hurricane intensity. With unexceptional but nonetheless hurricane strength, Charley then turned northeastward and took aim on the Azores. Capable of maintaining hurricane strength for only about three days, Charley fortunately weakened

to tropical storm strength prior to passing through the Azores. Though producing hurricane force wind gusts (close to 80 mph) at some Azores locations, no reports of casualties or damages were received. Shortly after passing through the Azores, Charley lost all tropical characteristics as it continued northeast towards the British Isles. Interestingly, just three days after Charley passed through the Azores, weakening Tropical Storm Bonnie followed Charley's footsteps and also moved through the Azores (see page 36).

Tropical Storm Earl *(September 26-October 3, 1992)*

Initially a tropical wave which emerged off of the African coast, this system was identified as a tropical depression a few hundred miles north of Hispaniola. Moving on a west-northwest track, the system then turned sharply to the north and then east, in advance of a cold front which had moved off of the United States eastern seaboard. The depression strengthened to Tropical Storm Earl as it continued moving east-southeast back into the open Atlantic Ocean. The tropical storm eventually dissipated without ever reaching hurricane strength. No casualties or damages were reported.

One other tropical cyclone (Hurricane Frances) formed during the 1992 hurricane season, but since it was named after September 30, 1992 (the end of Fiscal Year 1992), this storm will be included in next year's (Fiscal Year 1993) report.

Pacific Tropical Cyclones Affecting Guam and Hawaii

Typhoon Omar *(Guam, August 28, 1992)*

The most severe typhoon to strike Guam in more than a decade moved westward across the island on August 28, 1992. Typhoon Omar raked the island with sustained winds of 120 mph and gusts as high as 150 mph. Rainfall amounts reached 10 inches at some locations. Damages were estimated well up into the hundreds of millions of dollars, with as much as 90 percent of the island's buildings sustaining major damage. One death resulted from the typhoon, while as many as 132 people were injured. The storm left as many as 5,000 people homeless, and caused extensive damages to crops on the island. Guam had an incredibly active autumn, as four other typhoons passed very near or over

the island after Omar. However, since all of these typhoons occurred after the close of Fiscal Year 1992 (September 30, 1992), they will be discussed in next year's report.

Hurricane Iniki *(Hawaii, September 11, 1992)*

The most powerful hurricane to strike Hawaii in at least 90 years moved in from the south and made a direct hit on the island of Kauai on September 11, 1992. Hurricane Iniki slapped the island with wind gusts as high as 160 mph. The hurricane was blamed for at least three deaths, approximately 100 injuries, and damages estimated at close to $1.8 billion. The south shore of Kauai saw the most destruction, where storm surges of 4-6 feet were estimated. In terms of dollar damage, Iniki was the most destructive hurricane in history for Hawaii[17].

Dust Storms

On November 29, 1991, high winds associated with a frontal system blasted much of southern California, especially down the western side of the San Joaquin Valley. The winds generated a severe local dust storm, reducing visibility to near zero at times, which resulted in a huge pileup involving close to 100 vehicles. The accident occurred along a rural stretch of California's Interstate 5, about 170 miles north of Los Angeles. When the nightmarish accident scene was finally cleared up, a total of 17 people had lost their lives, while another 150 were injured. It was the worst interstate highway pileup in United States history, exceeding the Tennessee pileup that resulted from fog in December of 1990 (see last year's report, page 26).

Hailstorms

A severe hailstorm struck the central Florida counties of Lake, Orange and Seminole on March 25, 1992. The hailstorm caused damages estimated at close to $60,000,000. Vehicles and the nursery industry were particularly hard hit by the hailstorm, and accounted for most of the damages. No fatalities were reported.

[17]A comprehensive report on the hydrometeorological aspects of Hurricane Iniki is currently being prepared by the National Oceanic and Atmospheric Administration (NOAA). This report is expected to be available late in Fiscal Year 1993, and can be obtained by writing to: National Weather Service, NOAA, 1325 East-West Highway, Silver Spring, Maryland, 20910. Attention: Hydrometeorological Information Center - W/OH12x1.

STATISTICAL DATA

AND

PICTORIAL GRAPHICS

FOR

FISCAL YEAR 1992

TEN YEARS OF

STATISTICAL DATA

FOR

FISCAL YEARS 1983-1992

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